

DECLARATION OF MICHAEL G. JACOX

I, Michael G. Jacox do hereby declare and say as follows:

1. I received a Bachelor of Science Degree in Nuclear Engineering from the Georgia Institute of Technology in 1985. I received a Masters of Science Degree in Nuclear Engineering from the University of Idaho in 1992.

2. From 1998 to the present, I have been employed as an Assistant Director for the Commercial Space Center for Engineering (CSCE), Texas A & M University, where I have developed a strategic plan for a newly created NASA commercial space center which resulted in an increase of NASA funding from \$500K to \$1M annually. I planned and executed the campaign for industry input and support of the CSCE. I led the development of the first integrated payload design center at Texas A & M University.

3. From 1996-1998, I was employed as a Program Manager at the Space Dynamics Lab, Utah State University, where I defined, promoted and managed the \$50M Solar Orbit Transfer Vehicle (SOTV) space experiment and technology development program. I also completed the first ever system-level ground test of the Integrated Solar Upper Stage (ISUS) on time and within the \$15M budget.

4. From 1994-1996, I was employed as a Systems Engineer at Lockheed-Martin Idaho Technologies, where I managed a team of more than 30 engineers and scientists from NASA, the Naval Research Lab, Air Force Research Lab and industry in a highly successful \$1M system definition study of the ISUS space power and propulsion concept. I also managed a joint DOD-DOE nuclear biomodal systems engineering team that evaluated concepts and developed preliminary designs of combined power and propulsion reactors.

5. From 1989-1994, I was employed as a Senior Scientist at EG&G Idaho, where I conceived the design and managed the development and testing of the first integrated thermionic/heat-pipe module for nuclear bimodal applications. The multi-million dollar effort resulted in successful prototype testing. I also managed the design and installation of a unique multi-million dollar hot hydrogen test facility at the Idaho National Engineering Lab. I further originated the design of the Small-Ex-core Heat Pipe Thermionic Reactor (SEHPTR), led the SEHPTR conceptual design team, and received a patent covering the SEHPTR. I also developed and benchmarked the first three-dimensional neutronics model of the Advanced Test Reactor.

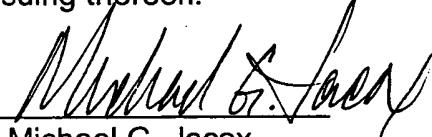
6. From 1985-1989, I was employed as a Nuclear Research Officer at USAF Weapons Lab, where I led the Air Force's space nuclear power application studies resulting in significant national program modifications and the development of the Military Space Reactor Initiatives. I also installed advanced nuclear reactor analysis codes on in-house computers.

Declaration of Michael G. Jacox
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7. While employed at EG&G, I contracted for the Idaho National Engineering Laboratory (INEL) under a DOE contract. At INEL, I conducted three experiments in which hydrogen was reacted with a catalyst, (K^+ , K^+), generated from aqueous K_2CO_3 , in an electrolytic cell containing nickel and platinum electrodes. The test conditions and results are shown in the attached report. As can be seen from the test results, 20 to 30 watts of excess heat was observed and in one instance the ratio of excess power to input electrolysis joule heating power was 850%.

8. The evidence presented in the attached report clearly demonstrates that a phenomenon takes place upon the admission of hydrogen to an electrolytic cell containing aqueous KCO_3 . This phenomenon generates heat in excess of that expected from any known chemical process, given the content of the reactants in the cell. A detailed analysis of all constituents was conducted to ensure that no chemical reactions were occurring which could be generating the excess heat observed.

9. I declare further that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issuing thereon.

By 
Michael G. Jacox

Date: 25 July 00

Experimental Verification by Idaho National Engineering Laboratory

Methods

A search for excess heat during the electrolysis of aqueous potassium carbonate (K^+/K^+ electrocatalytic couple) was investigated using cells supplied by HydroCatalysis Power Corporation and a cell fabricated by Idaho National Engineering Laboratory (INEL). To simplify the calibration of these cells, they were constructed to have primarily conductive and forced convective heat losses. Thus, a linear calibration curve was obtained. Differential calorimetry was used to determine the cell constant which was used to calculate the excess enthalpy. The cell constant was calculated during the experiment (on-the-fly-calibration) by turning an internal resistance heater off and on, and inferring the cell constant from the difference between the losses with and without the heater.

The general form of the energy balance equation for the cell in steady state is:

$$0 = P_{\text{appl}} + Q_{\text{htr}} + Q_{\text{xs}} - P_{\text{gas}} - Q_{\text{loss}} \quad (\text{III.1})$$

where P_{appl} is the electrolysis power; Q_{htr} is the power input to the heater; Q_{xs} is the excess heat power generated by the hydrogen "shrinkage" process; P_{gas} is the power removed as a result of evolution of H_2 and O_2 gases; and Q_{loss} is the thermal power loss from the cell. When an aqueous solution is electrolyzed to liberate hydrogen and oxygen gasses, the electrolysis power P_{appl} ($=E_{\text{appl}}I$) can be partitioned into two terms:

$$P_{\text{appl}} = E_{\text{appl}}I = P_{\text{cell}} + P_{\text{gas}} \quad (\text{III.2})$$

An expression for P_{gas} ($=E_{\text{gas}}I$) is readily obtained from the known enthalpy of formation of water from its elements:

$$E_{\text{gas}} = \frac{-\Delta H_{\text{form}}}{\alpha F} \quad (\text{III.3})$$

(F is Faraday's constant), which yields $E_{\text{gas}} = 1.48$ V for the reaction



The net faradaic efficiency of gas evolution is assumed to be unity; thus, Eq (III.2) becomes

$$P_{\text{cell}} = (E_{\text{appl}} - 1.48V)I \quad (\text{III.5})$$

The cell was calibrated for heat losses by turning an internal resistance heater off and on while maintaining constant electrolysis and by inferring

the cell constant from the difference between the losses with and without the heater where heat losses were primarily conductive and forced convective losses. When the heater was off, the losses were given by

$$c(T_c - T_b) = P_{appl} + 0 + Q_{xs} - P_{gas} \quad (\text{III.6})$$

where c is the heat loss coefficient; T_b is ambient temperature and T_c is the cell temperature. When a new steady state is established with the heater on, the losses change to:

$$c(T_c' - T_b) = P'_{appl} + Q_{htr} + Q'_{xs} - P'_{gas} \quad (\text{III.7})$$

where a prime superscript indicates a changed value when the heater was on. When the following assumptions apply

$$Q_{xs} = Q'_{xs}; P_{appl} = P'_{appl}; P_{gas} = P'_{gas} \quad (\text{III.8})$$

the cell constant or heating coefficient a , the reciprocal of the heat loss coefficient(c), is given by the result

$$a = \frac{T_c' - T_c}{Q_{htr}} \quad (\text{III.9})$$

In all heater power calculations, the following equation was used

$$Q_{htr} = E_{htr}/htr \quad (\text{III.10})$$

LIGHT WATER CALORIMETRY EXPERIMENTS

INEL EXPERIMENT I (DC Operation)

The present experiments were carried out by observing and comparing the temperature difference, $\Delta T_1 = T(\text{electrolysis only}) - T(\text{blank})$ and $\Delta T_2 = T(\text{electrolysis plus resistor heating}) - T(\text{blank})$ referred to unit input power.

The cell comprised a 10 gallon (33 in. x 15 in.) Nalgene tank (Model # 54100-0010). Two 4 inch long by 1/2 inch diameter terminal bolts were secured in the lid, and a cord for a heater was inserted through the lid.

The cathode comprised 1.) a 5 gallon polyethylene bucket which served as a perforated (mesh) support structure where 0.5 inch holes were drilled over all surfaces at 0.75 inch spacings of the hole centers and 2.) 5000 meters of 0.5 mm diameter clean, cold drawn nickel wire (NI 200 0.0197", HTN36NOAG1, Al Wire Tech, Inc.). The wire was wound uniformly around the outside of the mesh support as 150 sections of 33 meter length. The ends of each of the 150 sections were spun to form three cables of 50 sections per cable. The cables were pressed in a terminal connector which was bolted to the cathode terminal post. The connection was covered with epoxy to prevent corrosion.

The anode comprised an array of 15 platinized titanium anodes (15 - Engelhard Pt/Ti mesh 1.6" x 8" with one 3/4" by 7" stem attached to the 1.6" side plated with 100 U series 3000). A 3/4" wide tab was made at the end of the stem of each anode by bending it at a right angle to the anode. A 1/4" hole was drilled in the center of each tab. The tabs were bolted to a 12.25" diameter polyethylene disk (Rubbermaid Model #2666) equidistantly around the circumference. Thus, an array was fabricated having the 15 anodes suspended from the disk. The anodes were bolted with 1/4" polyethylene bolts. Sandwiched between each anode tab and the disk was a flattened nickel cylinder also bolted to the tab and the disk. The cylinder was made from a 7.5 cm by 9 cm long x 0.125 mm thick nickel foil. The cylinder traversed the disk and the other end of each was pressed about a 10 A / 600 V copper wire. The connection was sealed with

Teflon tubing and epoxy. The wires were pressed into two terminal connectors and bolted to the anode terminal. The connection was covered with epoxy to prevent corrosion.

Before assembly, the anode array was cleaned in 3 M HCl for 5 minutes and rinsed with distilled water. The cathode was cleaned in 3% H₂O₂/ 0.57 M K₂CO₃ and rinsed with distilled water. The anode was placed in the cathode support and the electrode assembly was placed in the tank containing electrolyte. The power supply was connected to the terminals with large cables.

The electrolyte solution comprised 28 liters of 0.57 M K₂CO₃ (Alfa K₂CO₃ 99%) in the case of the MC 3 cell or 28 liters of 0.57 M Na₂CO₃ (Alfa Na₂CO₃ 99%) in the case of the MC 2 cell.

The heater comprised a 57 ohm 1500 watt Incoloy coated cartridge heater which was suspended from the polyethylene disk of the anode array. It was powered by a regulated power supply. The voltage was measured with a digital meter, and the current was measured as a voltage across a precision resistor with a digital meter.

The stirrer comprised a 1 cm diameter by 43 cm long glass rod to which an 8 cm by 2.5 cm Teflon half moon paddle was fastened at one end. The rod passed through a bearing hole in the tank lid and through a bearing hole in the center of the anode array disk. The other end of the stirrer rod was connected to a variable speed stirring motor. The stirrer shaft was rotated at 4 Hz. With the stirrer connected, the stirrer motor drew 4.7 W. With the stirrer disconnected, the stirrer drew 4.4 W; thus, 0.3 W was the stirrer power.

Electrolysis was performed at 39.5 amps constant current with a constant current power supply. The cells were operated in the environmental chamber in the INEL Battery test Laboratory. The chamber maintained the average temperature of the cell surroundings within 1 °C. The bottom of the cell rested on a 1/2 inch thick sheet of Styrofoam.

The temperature was recorded with a series of Teflon-coated Type E thermocouples inserted in several places. The ambient temperature reference was a closed one-liter container of water

with a thermocouple nominally in the center of the water volume.

Data from thermocouples, voltages, and currents were logged by one of the Battery Lab's computer based data systems and recorded at 5 minute intervals. The delta temperature ($\Delta T = T(\text{electrolysis only}) - T(\text{blank})$) and electrolysis power were plotted. The heating coefficient was determined "on the fly" by the addition of heater power. The delta temperature $\Delta T_2 = T(\text{electrolysis + heater}) - T(\text{blank})$) and the electrolysis power and heater power were plotted.

Mass spectroscopy of the gasses evolving from the MC 3 (K_2CO_3) cell was performed using a VG Instruments model SXP-50 high -precision mass spectrometer with 0.01-amu mass resolution and 6 decade sensitivity.

A 100 ml sample of the 0.57 M K_2CO_3 electrolyte of the MC 3 (K_2CO_3) cell was removed after 20 days of cell operation, and a chemical analysis was performed on the electrolyte using an Inductively Coupled Plasma-Atomic Emission Spectrometer.

RESULTS

Light Water Calorimetry

The results of the electrolysis for INEL cell runs MC 2 and MC 3 at 39.5 A constant current appear in Figure 1 (hand plot of data by INEL scientists). As shown in Figure 1, the MC 3 (K_2CO_3) cell intercepts the Total Input Power axis at 35 W; whereas, the MC 2 (Na_2CO_3) cell intercepts the Total Input Power axis at 59 W. The input power to electrolysis gases given by Eqs. (III.2-III.5) is $(39.5)(1.48) = 58.5$ W. The production of excess enthalpy of 25 W is observed with the MC 3 (K_2CO_3) cell, and energy balance is observed with the MC 2 (Na_2CO_3) cell.

Mass spectroscopic analysis of the gasses evolved by the MC 3 (K_2CO_3) cell showed that a significant fraction of the sample was air with standard constituents. When the spectrum associated with air was removed, the residue showed a majority of diatomic hydrogen and oxygen gases in approximately the 2:1 proportion expected from the electrolysis and residual water vapor. There were no hydrocarbons, no metallic constituents or other anomalies except that a slightly higher than expected hydrogen to oxygen ratio was observed. No

tritium or deuterium measurements above normal background were observed.

Chemical analysis of an electrolyte sample from the MC 3 (K_2CO_3) cell after 20 days of operation found the following components at levels above the background levels in the water used to fill and replenish the cell: 1.7 ppm silicon, 1.1 ppm sulfur, and 46.5 ppm sodium in addition to the K_2CO_3 salt. Small quantities of silicon are known impurities in the nickel wire and may have also come from the glassware used in various processes. Sulfur is a common impurity in the salt, and it may have come from the resin beds used for water deionization. Sodium is a probable salt impurity, and it may also have come from hand contact with the system. The potassium was measured at 43,000 $\mu g/ml$ corresponding to a salt molarity of 0.55 M (within measurement error of the initial 0.57 molarity determined by weighing the salt and measuring the water for the initial charge). The electrolyte retained its molarity. The cell potential characteristics were essentially unchanged over the duration of operation. There were no nickel or other metallic compounds present in the electrolyte. A visual inspection of the cell showed that all of the structural components were intact. The cell comprised about 155 moles of nickel in the cathode, about 6.5 moles of titanium in the anodes, and about 13.7 moles of K_2CO_3 . The only material consumed in the cell was nano-pure deionized water.

INEL EXPERIMENT II (Pulsed Power Operation)

The MC 3 (K_2CO_3) cell was wrapped in a one-inch layer of urethane foam insulation about the cylindrical surface. The top was not insulated. The bottom of the cell rested on a 1/2 inch thick sheet of Styrofoam.

The cell was operated in a pulsed power mode. A current of 10 amperes was passed through the cell for 0.2 seconds followed by 0.8 seconds of zero current for the current cycle. The cell voltage was about 2.4 volts, for an average input power of 4.8 W. The electrolysis power average (Eq. (III.5)) was 1.84 W, and the stirrer power was measured to be 0.3 W. Thus, the total average net input power was 2.14 W. The cell was operated at various resistance heater settings, and the temperature

difference between the cell and the ambient as well as the heater power were measured.

RESULTS

Light Water Calorimetry

The results of the excess power as a function of cell temperature with the MC 3 cell operating in the pulsed power mode at 1 Hz with a cell voltage of 2.4 volts, a peak current of 10 amperes, and a duty cycle of 20 % appears in Figure 2.

Figure 2 shows that the excess power is temperature dependent for pulsed power operation, and the maximum excess power shown in Figure 2 is 18 W for an input electrolysis joule heating power of 2.14 W. Thus, the ratio of excess power to input electrolysis joule heating power is 850 %.

INEL EXPERIMENT III (Forced Convection Calorimetry Of INEL Cell)

INEL scientists constructed an electrolytic cell comprising a nickel cathode, a platinized titanium anode, and a 0.57 M K₂CO₃ electrolyte. The cell design appears in Appendix I. The cell was operated in the environmental chamber in the INEL Battery test Laboratory at constant current, and the heat was removed by forced air convection in two cases. In the first case, the air was circulated by the environmental chamber circulatory system alone. In the second case, an additional forced air fan was directed onto the cell.

The cell was equipped with a water condensor, and the water addition to the cell due to electrolysis losses was measured.

RESULTS

Light Water Calorimetry

The data of the forced convection heat loss calorimetry experiments during the electrolysis of a 0.57 M K₂CO₃ electrolyte with the cell appears in Table 1 and Figure 3. The comparison of the calculated and measure water balance of the INEL cell appears in Table 2 and Figure 4.

The intercept of the Net Input Power (calculated using Eq. (III.5)) axis of Figure 3 for both cases of forced convection is 13 w. Thus, 13 W of excess power was produced by the INEL cell. This excess power can not be attributed to recombination of the hydrogen and oxygen as indicated by the

equivalence of the calculated and measured water balance as shown in Figure 4.

F. 1

THERMAL CONDUCTANCE CALIBRATION (11/25)

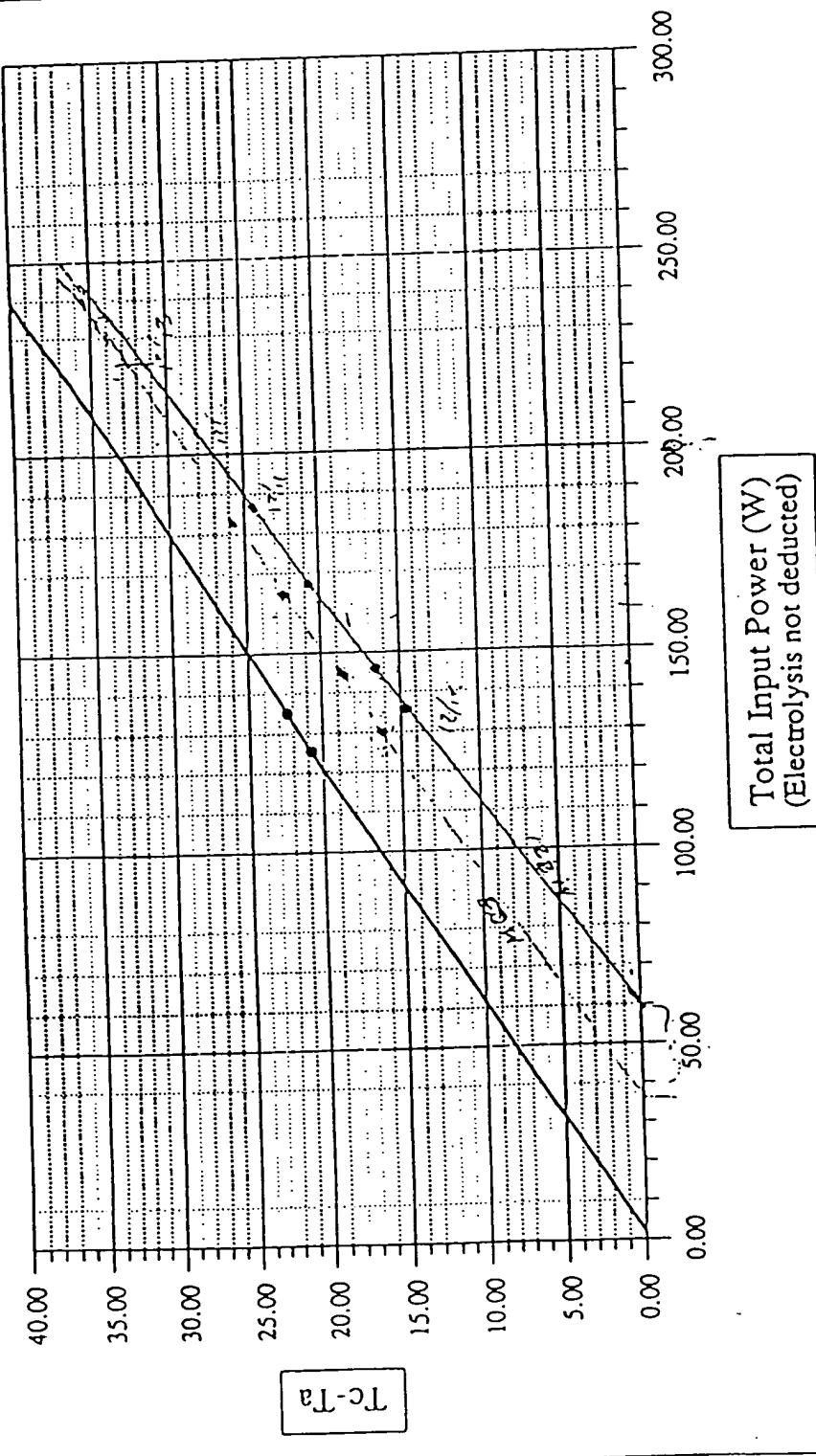


Figure 2.

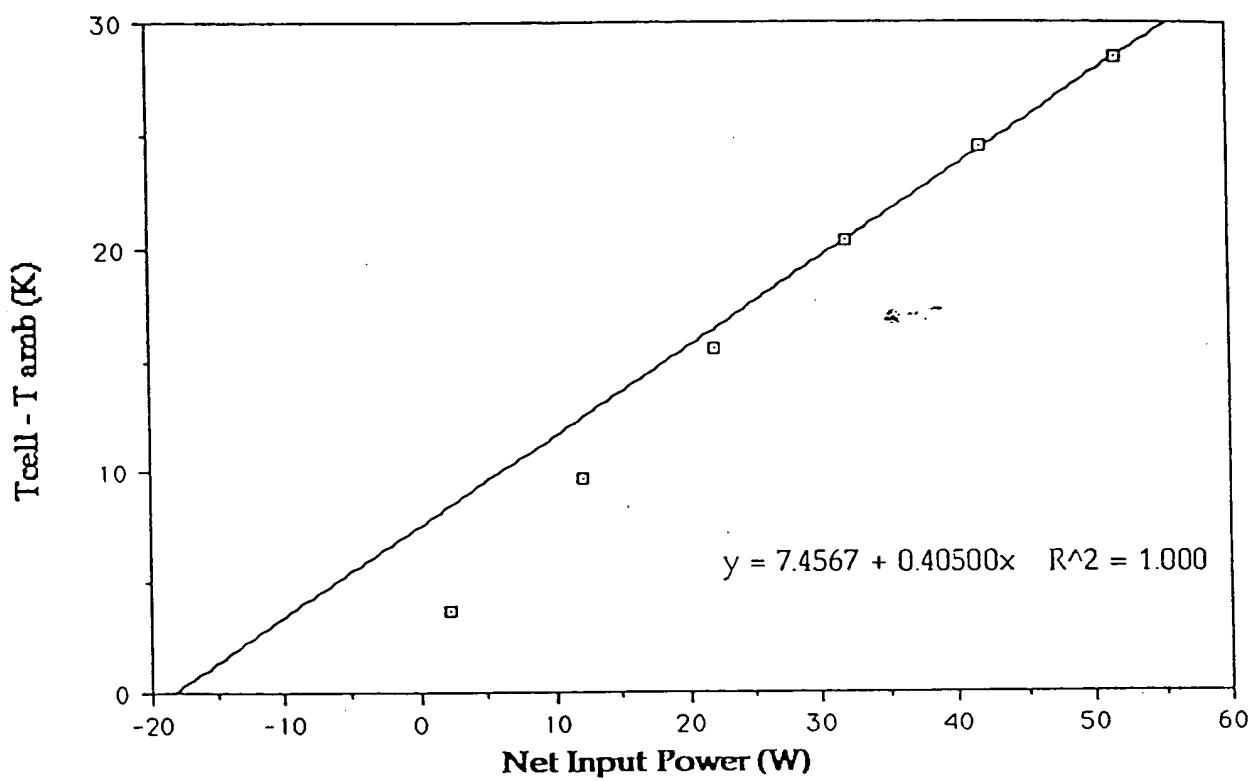
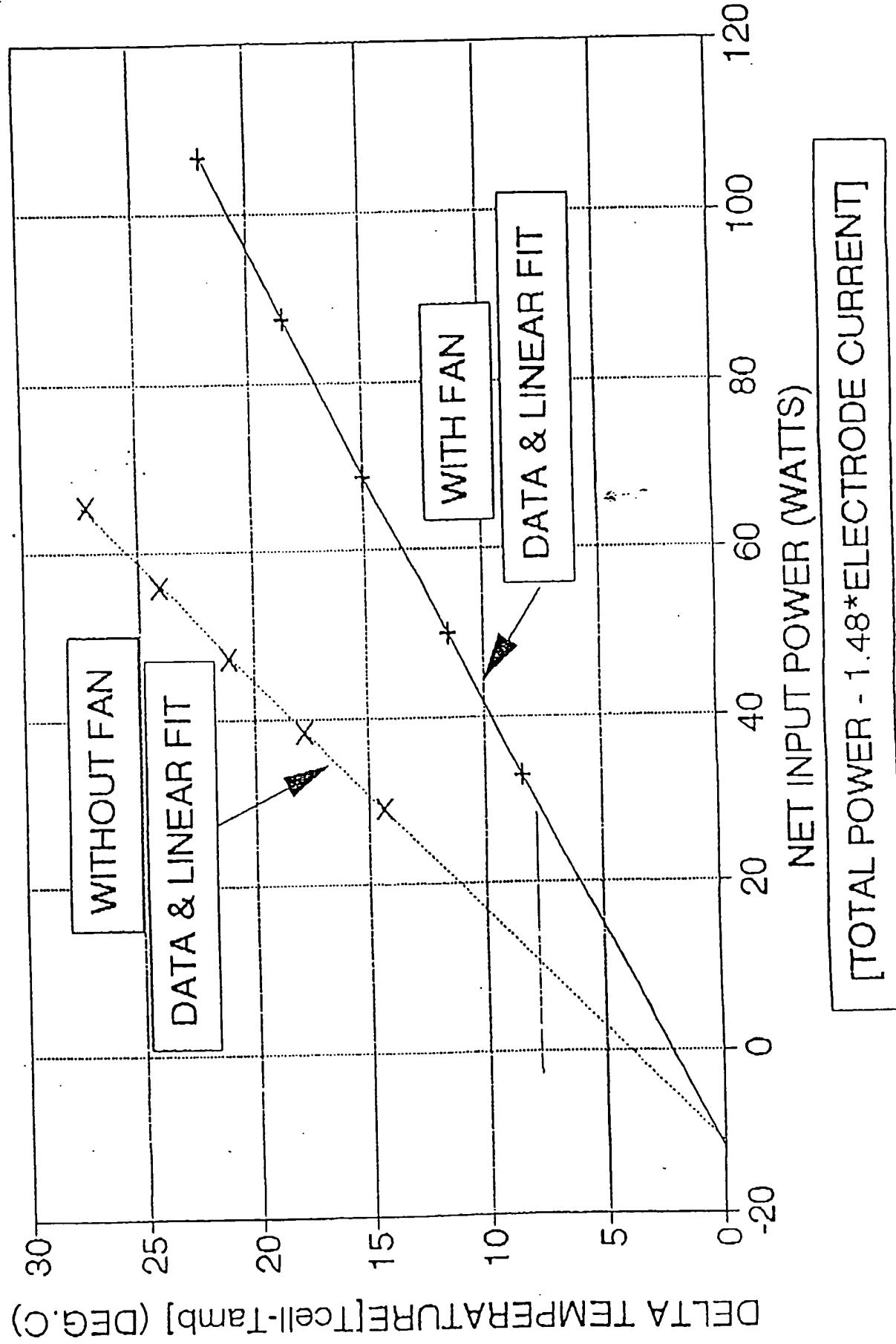


FIGURE 3.

IC1

T99 THRU T103 & T105 THRU T109



IC1 WATER ADDITION

1/9/93 THRU 1/29/93

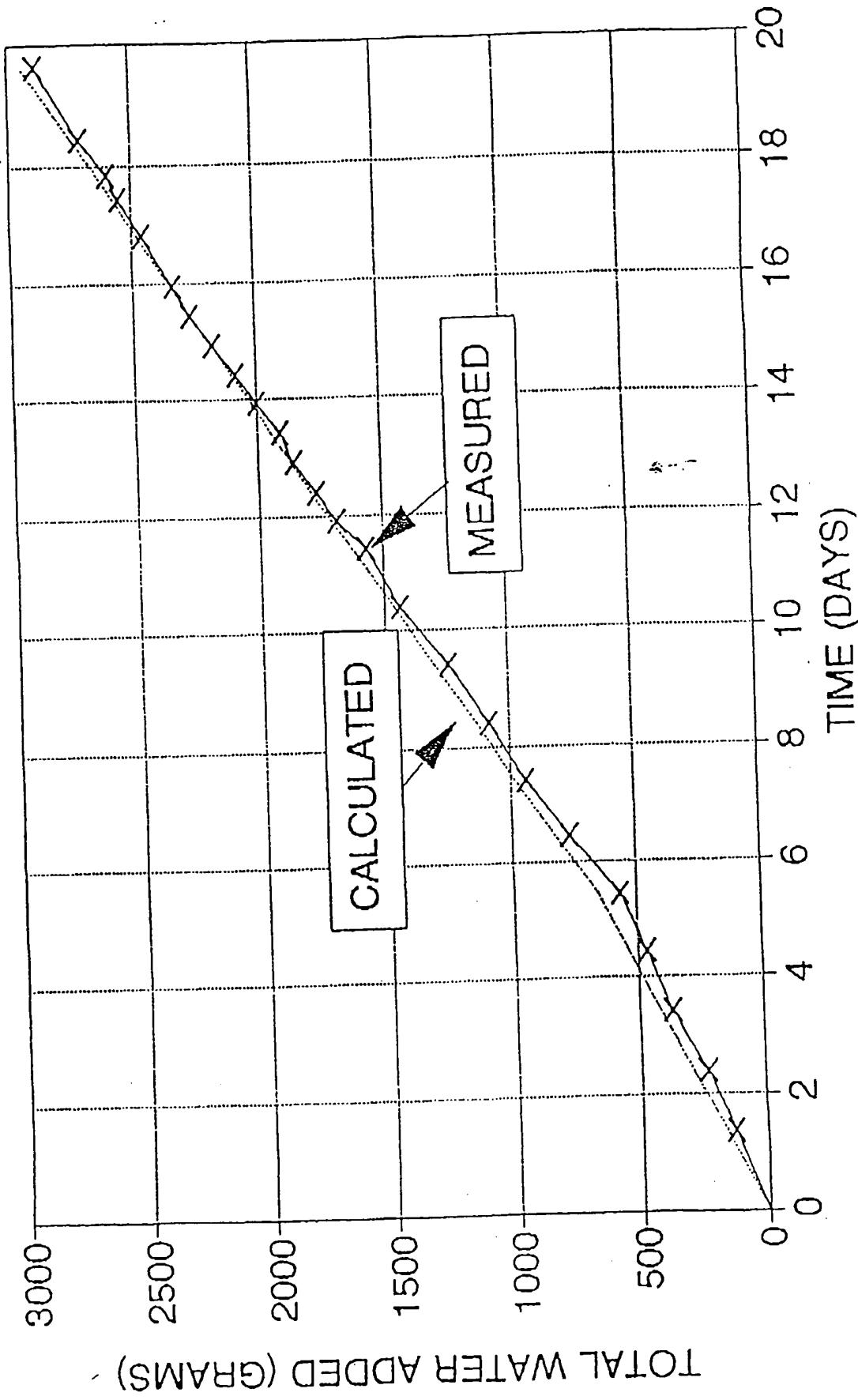


Table 1.
FILE IC1

TEST NO.	TOTAL POWER	DELTA TEMP	LF DT	DELTA TEMP	LF DT	PWR*A*1.48
T99	94.8	27.2	27.36265			65.2962
T100	85.2	24.05	23.93155			55.6962
T101	78.8	21.05	20.92933			47.2962
T102	67.8	17.75	17.71267			38.2962
T103	68.57	14.3	14.4138			29.0682
		18.24	-0.00042			-11.2638
T105	136.07			21.95	21.94573	106.5662
T106	117.05			18.42	18.42674	87.5462
T107	98.25			14.95	14.94844	68.7462
T108	79.45			11.47	11.47015	49.9462
T109	62.68			8.35	8.348937	33.0762
		17.45			-0.00082	-12.0538

Table 2.

IC1 WATER ADDITION ;FILE IC1WATE

DATE	TIME			QPRO	QPRO	DATE+TIME	ELECTRO	WATER	WATER	WATER	TOTAL	ADDED/CALC	
	HOURS	MINUTES	SECONDS					DATE	DAYS	AMPS	GRAMS	TOTAL	CALO
01/09/93	81	30	0	0.695633	33978.9	-0.00416667	16	0	0	0	0	0	0
01/11/93	7	15	0	0.302063	33980.3	1.402083333	15	131	131	169.9935	169.9935	0.77061781	
01/12/93	7	10	0	0.298611	33981.3	2.398611111	15	108	239	120.4645	290.4648	0.82863844	
01/13/93	7	20	0	0.311806	33982.31	3.411806556	14.94	131	370	121.9693	412.4473	0.89708425	
01/14/93	7	56	0	0.330556	33983.33	4.430655556	14.94	89	468	182.8582	835.1086	0.8677747	
01/15/93	7	50	0	0.326388	33984.33	5.426366889	14.93	102	661	118.8188	654.9243	0.8666875	
01/16/93	8	26	0	0.351369	33985.35	6.461388889	18.93	205	786	104.6302	810.6548	0.93465404	
01/17/93	8	19	0	0.346628	33985.36	7.446627778	19.93	165	934	169.8341	970.3887	0.9534651	
01/18/93	7	42	0	0.320833	33987.32	8.420833333	19.94	160	1084	158.6685	1135.935	0.95426301	
01/19/93	7	32	0	0.313888	33988.31	9.413888889	19.93	164	1236	158.4905	1295.488	0.95844903	
01/20/93	7	25	0	0.309028	33989.31	10.40902778	18.84	194	1432	159.9143	1465.369	0.98394292	
01/21/93	7	42	0	0.320833	33990.32	11.420833333	19.93	133	1686	162.511	1617.88	0.95731620	
01/21/93	10	28	0	0.811111	33990.81	11.911111111	19.93	110.5	1675.5	78.7489	1696.626	0.95754829	
01/22/93	7	32	0	0.313889	33991.31	12.413888889	19.93	83	1768.6	80.76369	1777.379	0.98937791	
01/22/93	10	37	0	0.817381	33991.82	12.917361111	19.93	92	1660.6	80.80513	1658.245	0.9568323	
01/23/93	7	32	0	0.313888	33992.31	13.413888889	19.84	48	1888.5	70.78976	1938.034	0.97856882	
01/23/93	10	18	0	0.804681	33992.8	13.904881111	19.83	102	1998.8	78.66744	2018.892	0.98088111	
01/24/93	7	28	0	0.311111	33993.31	14.411111111	19.93	84	2082.5	81.31128	2098.203	0.99281693	
01/24/93	10	20	0	0.805558	33993.81	14.905555556	19.83	93	2175.5	79.41613	2177.818	0.98902727	
01/26/93	7	38	0	0.318054	33994.32	15.418055556	19.93	94	2269.5	82.31512	2259.933	1.00423318	
01/25/93	20	1	0	0.834028	33994.83	15.93402778	19.93	66	2334.5	82.67261	2342.806	0.99846461	
01/26/93	10	31	0	0.688184	33995.89	16.78819444	19.83	122	2456.5	137.1919	2478.998	0.99052488	
01/27/93	7	46	0	0.322017	33996.32	17.42291667	19.93	98	2552.5	101.9468	2681.944	0.98859024	
01/27/93	10	35	0	0.732339	33996.73	17.832363888	19.84	55	2608.5	85.8408	2647.784	0.98516331	
01/28/93	7	47	0	0.324506	33997.32	18.42430556	19.93	107	2716.5	85.03047	2742.815	0.99004101	
01/29/93	12	60	0	0.634722	33998.53	18.63472222	19.94	171	2886.5	194.5085	2937.523	0.98269741	

Appendix I.

DATE: December 15, 1982
TO: Richard Deaton MS 4139, Ext. 6-2016, FAX 6-2681
FROM: R. L. Drexler MB 3123, Ext. 6-1789
SUBJECT: INEL CELL CATHODE ESTIMATE

Attached are the following sketches and revised sketches:

Cathode Assembly for INEL CELL	12/15/82
Narrow Cathode Strap for INEL CELL	12/15/82
Cathode C-1 INEL CELL	12/2/82
Mandrel - Cathode Winding	12/8/82
Electrode Bus Ring INEL CELL	12/15/82

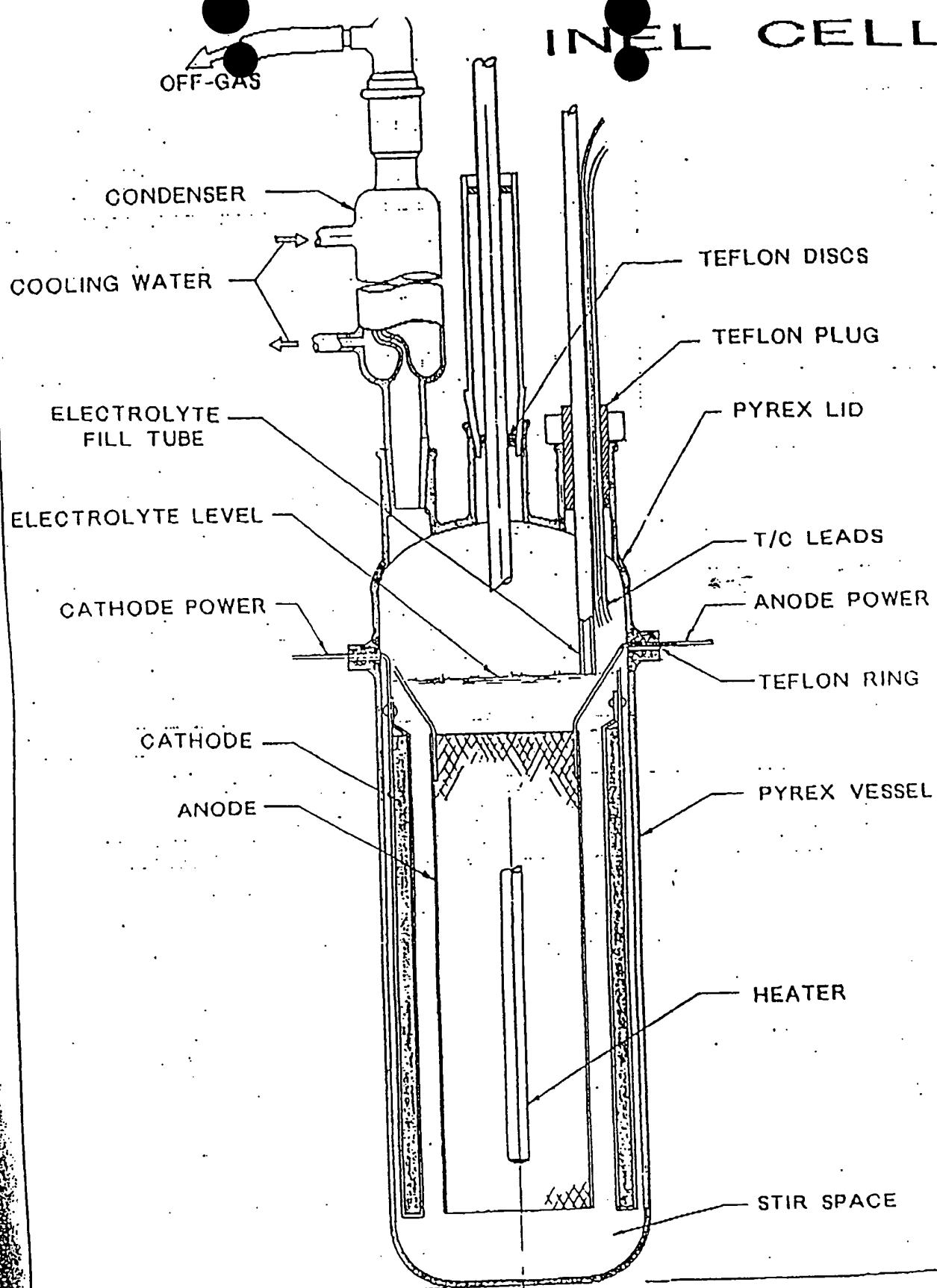
Would you please give us a firm estimate for fabrication of two "identical" cathode assemblies per the 12/15/92 sketch, and two Electrode Bus Rings per the 12/15/92 sketch.

The cathode windings could be made on a mandrel per the sketch 12/8/92 or similar suitable arrangement.

These cathodes and bus rings are similar to those previously fabricated except:

1. The straps are 0.5 in. wide rather than 1.0 in. wide. These narrower straps would be flat rather than arched to fit the winding curvature.
2. There are no secondary straps as were added to the windings of the first cathode assembly.
3. Windings would be less dense than the first winding. A much steeper pitch is probably necessary to achieve the more open wind.
4. Weight of the NI-200 wire of each winding should be very close to 3.33 pounds, and both windings should have the same weight as closely as possible.
5. Slots in the Teflon Buss Ring for the cathode straps would be 0.50 wide rather than the 1.0 width of the first ring.

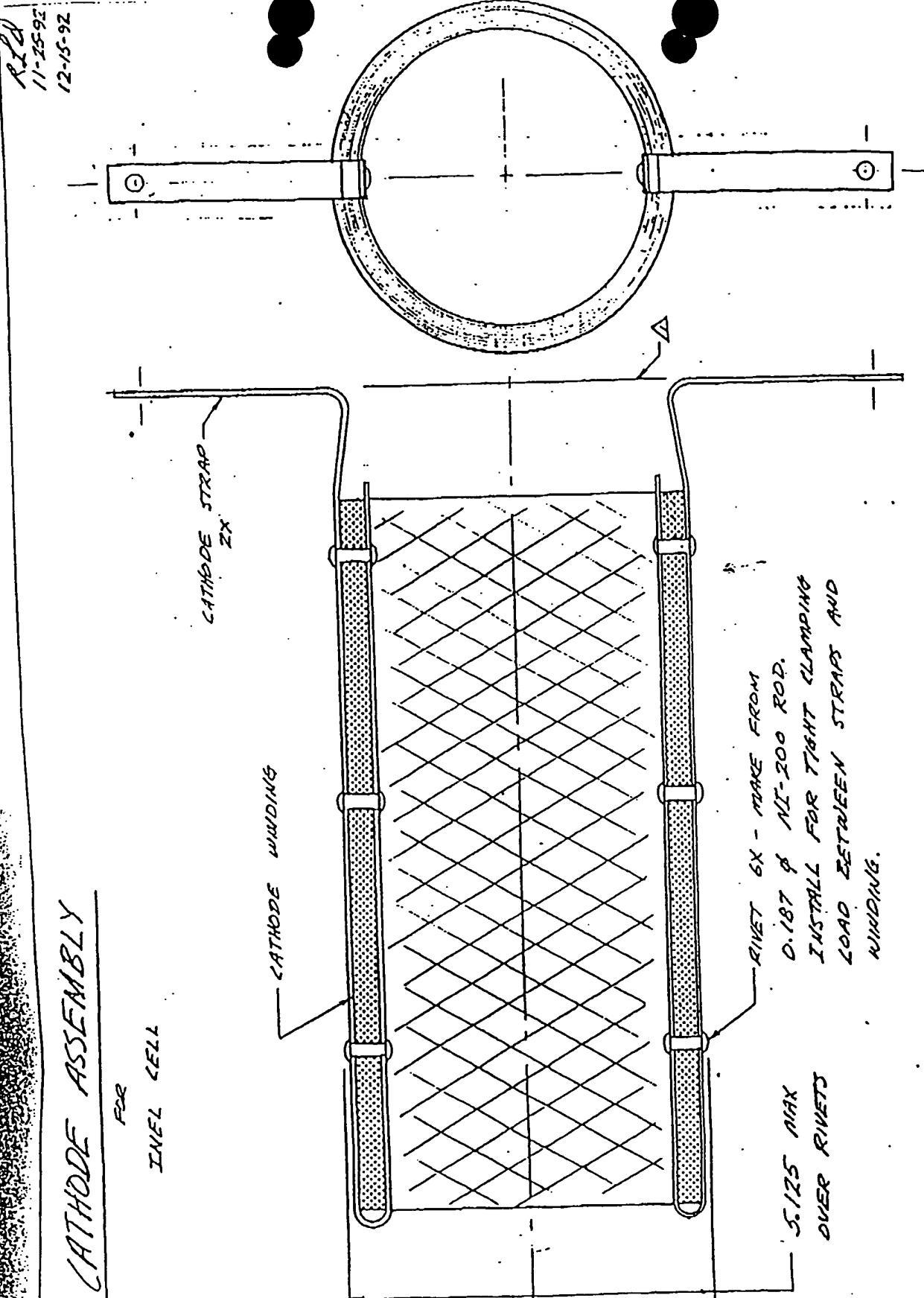
INEL CELL



0 1 2 3 4 5 6
INCHES

CATHODE ASSEMBLY

FOR
INEL CELL



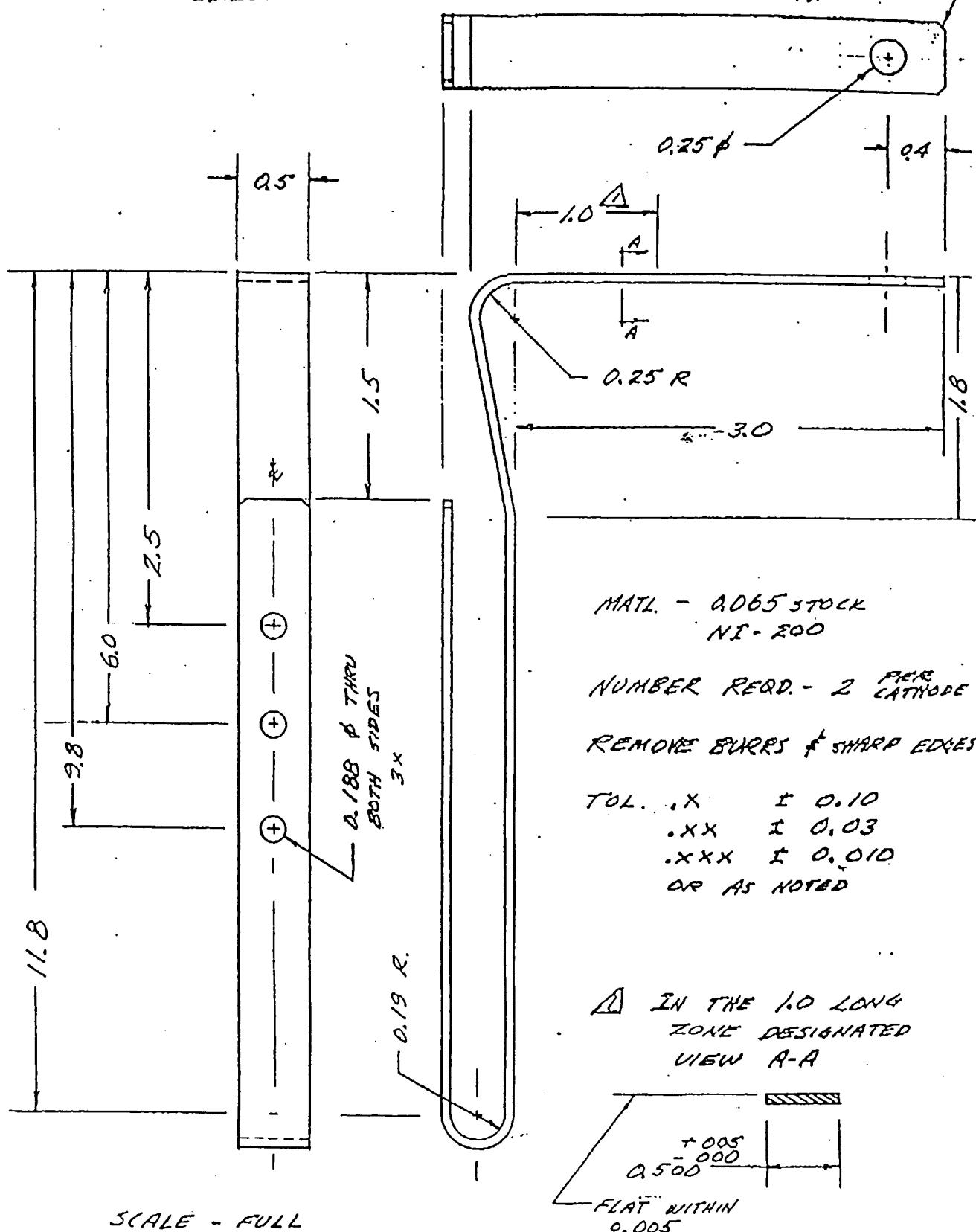
RIVET 6X - MAKE FROM
0.187 & NI-200 ROD.
5.125 MAX
OVER RIVETS
LOAD BETWEEN STRAPS AND
WINDING.

△ ALIGN BOTH STRAPS
IN PLANE AT 90°
WITH WINDING &

NARROW CATHODE STRAP

12-15-92

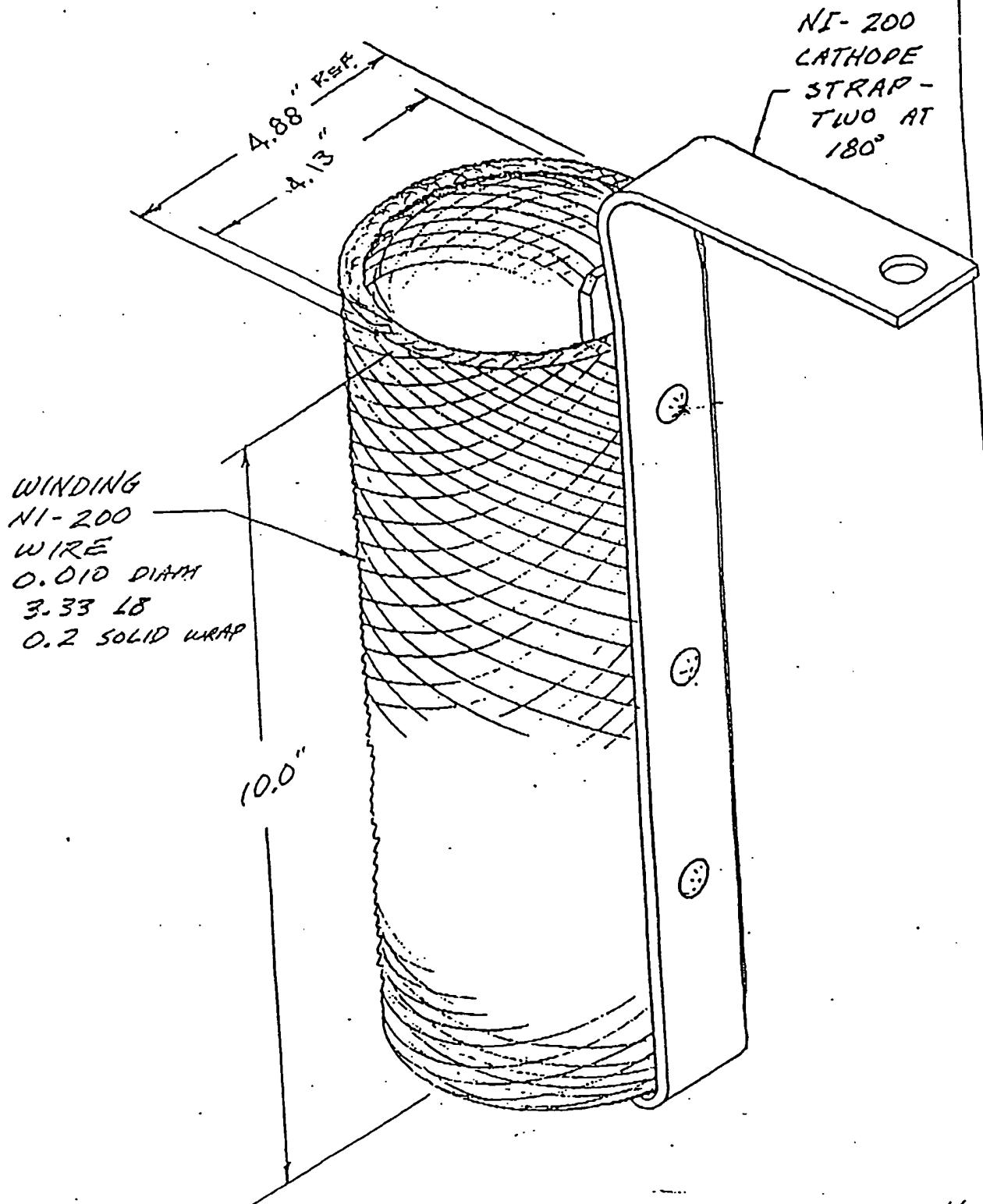
FOR
INEL CELL



10-1992
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CATHODE C-1

INEL CELL



NUMBER REFD. — ONE PER CELL

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